

The Effects of Transcranial Focused Ultrasound on Alpha Power



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Introduction

- Increased alpha (8-12 Hz) power has been associated with creative ideation (Fink, 2014) and meditative states (Cahn, 2006).
- Transcranial focused ultrasound (tFUS), a type of non-invasive ultrasound stimulation, has been shown to effectively modulate neural oscillations (Sanguinetti, 2022).
- Tuning the pulse repetition frequency to the peak individual alpha frequency may have a preferential effect on alpha oscillations. If tFUS be shown to significantly influence alpha power in human subjects, this would have serious implications for future study of psychiatric disorders and development of treatment options.
- Stimulation target: posterior cingulate cortex (PCC), a central node in the default mode network containing a proposed alpha generator (Rusiniak et al., 2018).

- Stimulation conditions** ($n=30$; 10 per condition): Sham (no energy), 10 Hz pulse repetition frequency (PRF), Individual Alpha Frequency (IAF) PRF

tFUS Stimulation Parameters:

Acoustic Frequency (AF)	Pulse Repetition Frequency (PRF)	Pulse Duration (PD)	Duty Cycle
500 kHz	10.0 Hz or IAF	5 ms or 2500 cycles	5.0 %

Table 1. tFUS Parameters

- EEG data was cleaned by an automated pipeline. Low frequency drifts were removed with a filter, stationary artifacts removed with SASICA and MARA, and non-stationary artifacts were removed with ASR.
- Individual alpha frequency was estimated following Corcoran et al., 2018 which uses Welch's method for power spectral density.

- Figure 2** was created by taking the mean alpha power of the subjects in each given condition at each electrode. The head plot depicts mean alpha power values at each electrode.

- Alpha change (**Figure 3**) was calculated by taking the difference of post- and pre-stimulation alpha power values at each electrode and calculating mean values across all 10 participants for each given condition.

- A 1-way ANOVA for the differences in alpha power at each electrode yielded significant effects at electrodes FP1, CP2, and CP4.

General trends:

- Sham - increased alpha power post-stim
- 10 Hz - mixed alpha power changes post-stim
- IAF - decreased alpha power post-stim

Survey Data: VAMS

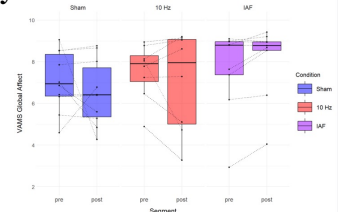


Figure 4. Visual Analog Mood Scale Global Affect Score Pre and Post Stimulation

- Note: Linear mixed model regression with fixed effects coefficients (95% CI) for IAF change showed insignificant positive ($p=0.11$) trend for Global Affect in IAF condition.
- The most consistent and significant effect found between pre- and post-stimulation conditions was an **increase in alpha frequency in only the IAF condition**. This significance was established via a 1-way ANOVA ($p=0.005$) displaying significant differences between the three conditions and a linear mixed model regression with fixed effects coefficients (95% CI) for IAF changes showing a significant alpha increase ($p=0.003$) in only the IAF condition, with an average increase in alpha frequency of about 0.33723 Hz.

Methods and Materials

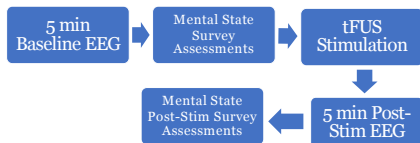


Figure 1. Outline of experimental procedures.

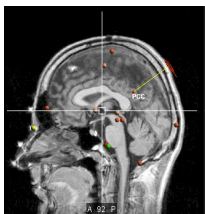


Image 1. Posterior Cingulate Cortex Target Neuronavigation Display

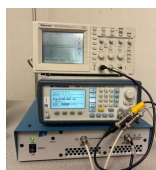


Image 2. Ultrasound amplifier, transformer, and function generator



Image 3. Ultrasound transducer

- For each pre- and post-stimulation period, EEG recordings were broken into 4-second epochs with a Hamming window to reduce edge artifacts. A Fast Fourier Transform (FFT) was used and then log-transformed to get the frequency bandpower. Everything in the 7-13 Hz range was summed, providing alpha power at each electrode.

Findings

Alpha Power Head Plots

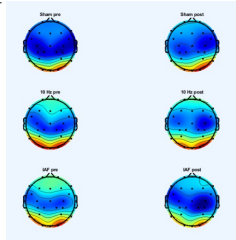


Figure 2. Alpha Power Head Plots (Pre- vs Post-Stim)

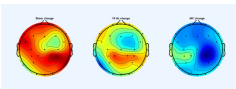


Figure 3. Alpha Power Change Head Plots

Conclusions and Discussion

- A correlation between the absolute value of the change in IAF and the change in alpha power in the IAF PRF condition resulted in $r=-0.01$, $p=0.97$. This indicates practically zero correlation between individual alpha frequency change and alpha power. This signifies that frequency is modulating independent of power.
- One proposed tFUS mechanism is disrupted alpha synchrony yielding modulatory effects. Considering this proposed mechanism, one would expect a correlation between alpha frequency and alpha power behavior. This was not observed, leading to speculation as to the mechanism at play.

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